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Brief Report

# Spectral information in nonspeech contexts influences children's categorization of ambiguous speech sounds

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ABSTRACT

For both adults and children, acoustic context plays an important role in speech perception. For adults, both speech and nonspeech acoustic contexts influence perception of subsequent speech items, consistent with the argument that effects of context are due to domain-general auditory processes. However, prior research examining the effects of context on children's speech perception have focused on speech contexts; nonspeech contexts have not been explored previously. To better understand the developmental progression of children's use of contexts in speech perception and the mechanisms underlying that development, we created a novel experimental paradigm testing 5-year-old children's speech perception in several acoustic contexts. The results demonstrated that nonspeech context influences children's speech perception, consistent with claims that context effects arise from general auditory system properties rather than speech-specific mechanisms. This supports theoretical accounts of language development suggesting that domain-general processes play a role across the lifespan.



## Introduction

Acquiring native language phonetic categories presents a complex learning problem because mappings from acoustics to phonetic categories are not straightforward. Young learners must discover acoustic dimensions that are relevant to distinguishing native phonetic categories and learn how variability along these dimensions relates to categories. Learners accomplish this despite much acoustic

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variability; acoustic dimensions signaling phonetic categories vary radically across talkers (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967; Nygaard, Sommers, & Pisoni, 1994; Strand & Johnson, 1996) and within talkers (Hillenbrand, Getty, Clark, & Wheeler, 1995; Liberman, 1957; Lisker & Abramson, 1967). Adult listeners rely on context to deal with acoustic variability (see Repp, 1982, for a review). The mechanisms underlying the influence of context on adult speech categorization have been well investigated (e.g., Holt & Lotto, 2002; Lotto & Holt, 2006). Context is likely to be important for language learners as well; for example, infants and young children are sensitive to the lexical context in which phonemes occur (e.g., Swingley, 2009; Thiessen & Yee, 2010). To better understand the developmental progression of children's use of contexts in speech perception and the mechanisms underlying that development, we created a novel experimental paradigm testing 5-year-old children's speech perception in several acoustic contexts. This paradigm allows us to test the theoretical claim that context effects in speech perception arise from general auditory processing rather than speech-specific mechanisms.

Context can be powerful in resolving perceptual ambiguity. For example, when perceptually ambiguous sounds from a /d/-to-/t/ series are followed by *-ash*, making a series that varies from *dash* to *tash*. people are more likely to categorize tokens as /d/ (consistent with the real word *dash*), whereas the same tokens are more often categorized as /t/ in *-ask* contexts that vary perceptually from *dask* to the real word *task* (Ganong, 1980). Visual context also disambiguates acoustics; watching faces articulate /aba/ or /ada/ shifts categorization of perceptually ambiguous acoustic tokens to be consistent with visual faces (Bertelson, Vroomen, & de Gelder, 2003). Moreover, phonetic context also influences speech categorization; when sounds from a /ga/-to-/da/ series are preceded by /al/, they are more often perceived as /ga/, whereas sounds that are preceded by /ar/ are more often perceived as /da/ (Mann, 1980).

Context sounds need not be speech in order to influence categorization of speech targets. Nonlinguistic tones that mimic critical spectral characteristics of /al/ and /ar/ shift perception of a /ga/-to-/da/ continuum similarly (Fowler, Brown, & Mann, 2000; Holt & Lotto, 2002; Lotto & Holt, 2006; Lotto & Kluender, 1998; Lotto, Sullivan, & Holt, 2003). Thus, it seems that general auditory characteristics of context, not specific to the speech signal, can influence speech categorization. In the example above, the /al/ and nonspeech tones that model it possess relatively higher acoustic frequencies and shift perception of the speech targets toward /ga/, the response alternative possessing lower frequency information. Conversely, speech (/ar/) or tone contexts with relatively lower frequencies shift perception toward /da/, the higher frequency response alternative. These spectrally contrastive effects have been replicated across adult categorization of vowels (Holt, Lotto, & Kluender, 2000), lexical tones (Huang & Holt, 2009, 2011), and other consonants (Holt, 1999; see Lotto & Holt, 2006, for a review). In each case, speech categorization is robustly influenced contrastively by the frequencies of sounds adjacent to the targets, and this influence appears to originate from very general properties of auditory processing not specific to speech (Lotto, Kluender, & Holt, 1997).

The claim that context effects arise from domain-general auditory processes is consistent with theoretical accounts that rely on domain-general mechanisms to explain language development (e.g., Saffran & Thiessen, 2007). However, it is as yet unclear whether these domain-general mechanisms play a role in context effects in speech perception for infants and children. Although context effects on speech perception have been demonstrated during infancy (Fowler, Best, & McRoberts, 1990), such demonstrations have focused on speech contexts. The impact of nonspeech contexts on speech categorization has been tested only in adults (e.g., Holt, 2005, 2006a; Lotto & Kluender, 1998). Discovering whether children are similarly influenced by nonspeech contexts is important for understanding the contribution of these domain-general processes to language development.

These processes are a plausible contributor to language development only if they are available to young language learners, but children might not be able to use nonlinguistic context like adults. One possibility is that children lack the cognitive capacity necessary to use long-term acoustic contexts such as those that evolved over several seconds of acoustic input in the Holt (2005, 2006a) studies. Children may lack memory resources necessary to store spectral information gained from context in order to use it by the time the to-be-interpreted signal arrives. Alternatively, the effect of nonlinguistic contexts on speech categorization may depend on strategies developed as a consequence of expertise in speech perception rather than as a consequence of domain-general perceptual processing.